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THE INVASION OF S.W. AUSTRALIA BY THE ORANGE PALMDART *CEPHRENES AUGIADES SPERTHIAS* (FELDER) LEPIDOPTERA, HESPERIIDAE, AND THE SUBSEQUENT INCREASE IN SPECIES ASSOCIATED WITH THE FRONDS OF THE CANARY ISLAND DATE PALM *(PHOENIX CANARIENSIS)*

By MICHAEL JOHN HUTCHISON, Geography Department, University of Western Australia, Nedlands.

ABSTRACT

The orange palmdart butterfly *Cephrenes augiades sperthias* (Felder), has spread throughout much of the Perth metropolitan area and to several country centres since it was first recorded near Wanneroo in 1977. The dispersal pattern of this species suggests that it has been aided by humans carrying infested palms to reach several points, from where it has been able to diffuse (in the adult stage) into adjacent areas containing the larval foodplant.

Canary Island date palms (*Phoenix canariensis*) with fronds uninfested by *C. augiades sperthias* in common with most exotic plant species have a depauperate associated fauna. The fronds of *P. canariensis* invaded by *C. augiades sperthias* tend to have a more diverse associated fauna than the fronds of palms that remain uninvaded. Evidence suggests that this is due to shelters constructed by *C. augiades sperthias* larvae being utilized by additional species and the establishment of new food chains.

INTRODUCTION

Various studies have shown that, compared to indigenous plants, exotic plant species generally have a depauperate fauna (e.g. Birks, 1979; Recher 1979; Southwood 1961 and Southwood et al., 1982). Over time an exotic plant species may accumulate an assemblage of organisms with which it was originally associated in its native region, as people intentionally and unintentionally introduce them (Elton, 1958). Indigenous species may also become associated with exotic plants. The number of these species has been positively related to the abundance of the exotic plant and the length of time since its introduction (Southwood, 1961). The exotic palms (family Arecaceae) planted mainly in parks and gardens in south-western Australia have recently begun to rapidly accumulate an invertebrate fauna. In 1977 the orange palmdart butterfly *Cephrenes augiades sperthias* was recorded from a nursery near Wanneroo, that had just imported palms from Queensland (Hutchison 1983). (For notes on the natural distribution of this species in eastern Australia see Hutchison (1983)). Orange palmdart larvae feed only on members of the plant family Arecaceae. Since 1977 the palmdart butterfly has caused concern because of the damage its larvae do to palm foliage.

Figure 1. Orange palmdart larval shelters (A) and orange palmdart larva (b).

Larvae construct shelters (see Figure 1) by binding two adjacent leaflets or two sides of a leaflet together with strong strands of silk. Larvae then eat the palm foliage from the safety of these shelters. A larva may construct and vacate several shelters during its lifetime. Pupation also takes place within a shelter.

It was decided to map the pattern of dispersal up until mid 1986, of *C. augiades sperthias* in south-western Australia, to test the hypothesis that humans had assisted the dispersal of the butterfly within the region. If this had been the case, one would expect a dispersal pattern consisting of multiple nodes to which palmdarts were taken by humans, from which the palmdarts had diffused into surrounding areas on their own. For example, the myxomotosis virus had a dispersal pattern such as this in Britain (Thompson and Warden 1956: 154).

It was also decided to compare the diversity of fauna associated with fronds of palms infested with *C. augiades sperthias* larvae, with the diversity of fauna associated with the fronds of palms uninfested by *C. augiades sperthias*. It was hypothesised that the shelters constructed by palmdart larvae would be used as refuges by additional species, and that both these species and *C. augiades sperthias* might form the bases of new food chains. Thus one would expect to find a more diverse assembleage of species associated with the fronds of infested palms.

METHODS

Data required to determine the dispersal pattern of the orange palmdart was gathered through the use of illustrated questionnaires (distributed among W.A. Naturalists' Club and Palm and Cycad Society members), media publicity, direct contact with people in the nursery business and through examination of labelled palmdart specimens held in the collections of the W.A. Museum, the W.A. Department of Agriculture and the University of W.A.'s Zoology Department. Positive and negative data were then plotted onto a 1:40 000 series of maps of the Perth metropolitan area, and the annual limits of dispersal were then drawn in by eye. Boundaries were drawn so as not to cross areas in which palms were absent (generally areas without houses parks or gardents). These data were later plotted on a 1:120 000 map, produced with the assistance of the Arc-Info computer program. Scales have been reduced for this publication.

For the study of the fauna associated with the fronds of infested and uninfested palms, one species of palm (*P. canariensis*) was chosen in order to reduce the number of variables. This palm is one of the most common palms growing in and near Perth. Fifty palms, located at 13 different sites in the Perth metropolitan area (see Figure 2) were chosen to be sampled. Sixteen palms (from sites 2,

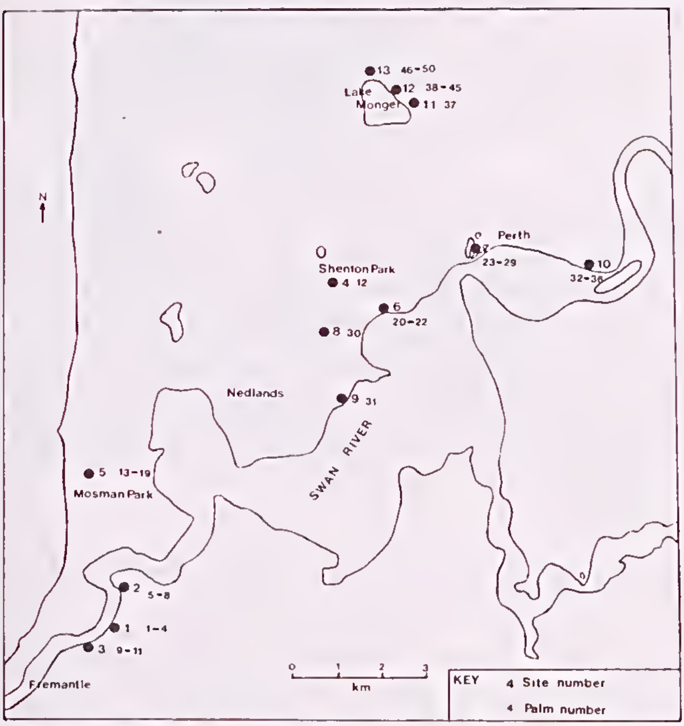


Figure 2. Location of survey sites.

10 and 12) were uninfested by *C. augiades sperthias* larvae. The fifty palms ranged in height from approximately three metres to five metres. The maximum height was related to the accessibility of fronds and the minimum height for a frond size of at least 200 leaflets, excluding the modified spikey leaflets found at the base of the fronds. Southwood et al. (1982) found no clear relationship between tree size and the number of arthropod species found on trees. It was concluded therefore that the variation in the size of the palms being examined would have little if any effect on the results obtained in this study.

One frond per palm was examined in April, May and July 1986. It would have been better to examine more fronds per palm each survey, but lack of time and assistance precluded a more extensive examination. Each frond examined in April and May was marked with tape to prevent re-examination in a subsequent survey. In order to standardize the field procedure 200 leaflets per frond were searched for specimens. The count began from just above the modified spiky leaflets at the base of a frond. The upper boundary of the 200 leaflets to be searched was marked with tape.

After marking the upper boundary the number of palmdart larval shelters occurring among the 200 leaflets was recorded. Subsequently, leaflets lacking shelters were examined closely for arthropods. These were collected, killed and stored in labelled vials for later identification. Leaflets with shelters were examined next. Shelters were held at the mouth of a jar and opened carefully with a brush. Any arthropods present in the shelters dropped into the jar. These were killed and stored as described above.

Note was made of the number of shelters among the 200 leaflets examined. Observations I considered significant were also recorded in the field notes. These observations included behaviour of arthropods on adjacent fronds, species common on adjacent fronds and birds foraging among the fronds.

Collected specimens were identified, then the Shannon-Weaver diversity index, H', recommended by Price (1975) as a simple means to estimate species diversity, was calculated for each palm, using the following formula. $H' = \Sigma p_i \log_e p_i$ where p_i is the proportion of the ith species in the total sample. As H' is calculated using natural logarithms, communities with one or less species are attributed with a value of zero. In addition, correlation coefficients and simple linear regressions were used to help analyse relationships between species diversity and infestation of palms by orange palmdarts. The Chi squared test was used to see if significant differences in the number of arthropods and species associated with infested and uninfested palms existed.

THE DISPERSAL PATTERN

Results

The dispersal pattern of the orange palmdart in the Perth metropolitan area (see Figures 3 and 4) appears to consist of isolated colonies and several centres from which palmdarts have diffused into surrounding areas. The oldest isolated colony (near Wanneroo) is dated 1977 and the oldest dispersal centre is dated 1979. The youngest dispersal centre is dated 1984 and the youngest isolated colony 1986.

Where palmdarts have apparently diffused into surrounding areas, it appears that diffusion northwards is generally most rapid, especially in the coastal suburbs. By the end of 1984, a large area of Perth was populated by orange palmdarts. Apparently palmdarts have not established themselves east of Beechboro or Gosnells. Dates were not available from some areas where palmdarts are known to exist, and not even distributional data could be obtained from some other areas. These areas are represented by either broken boundaries or question marks on Figures 3 and 4.

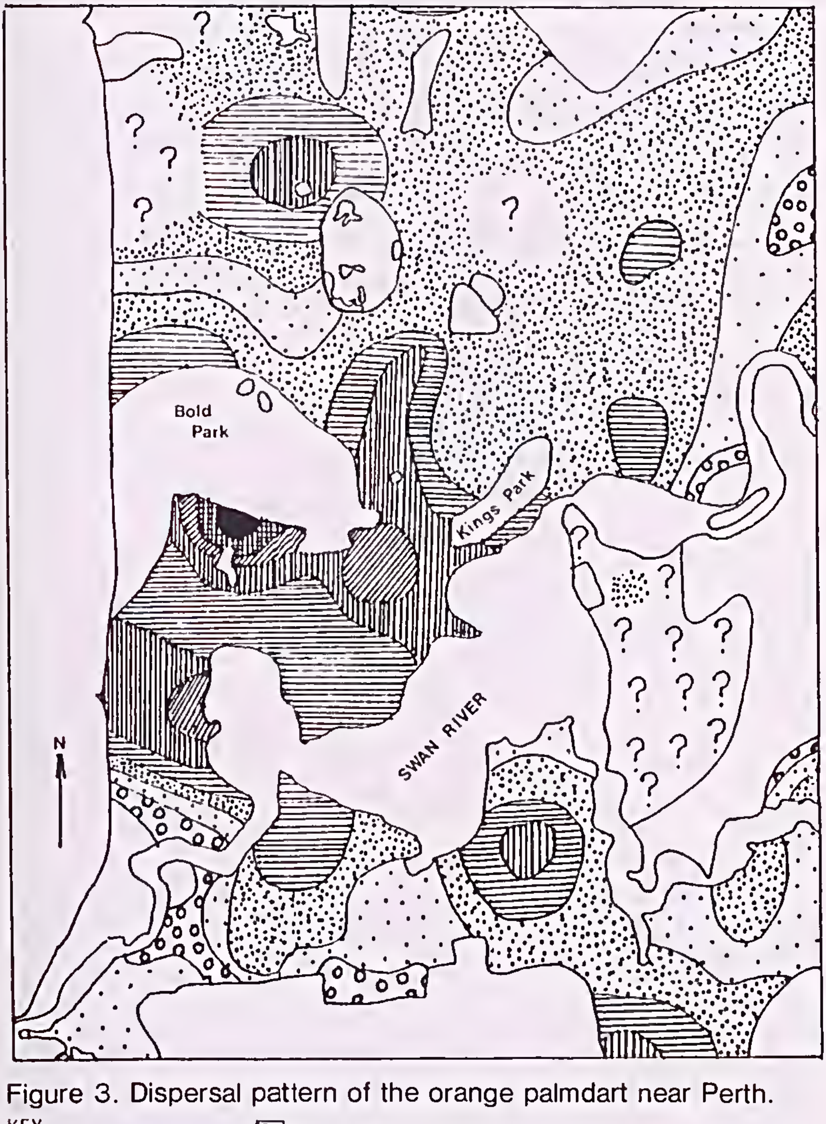
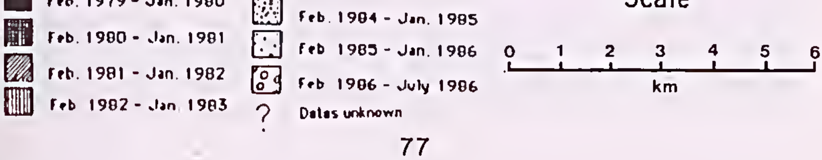


Figure 3. Dispersal pattern of the orange palmdart near Perth.



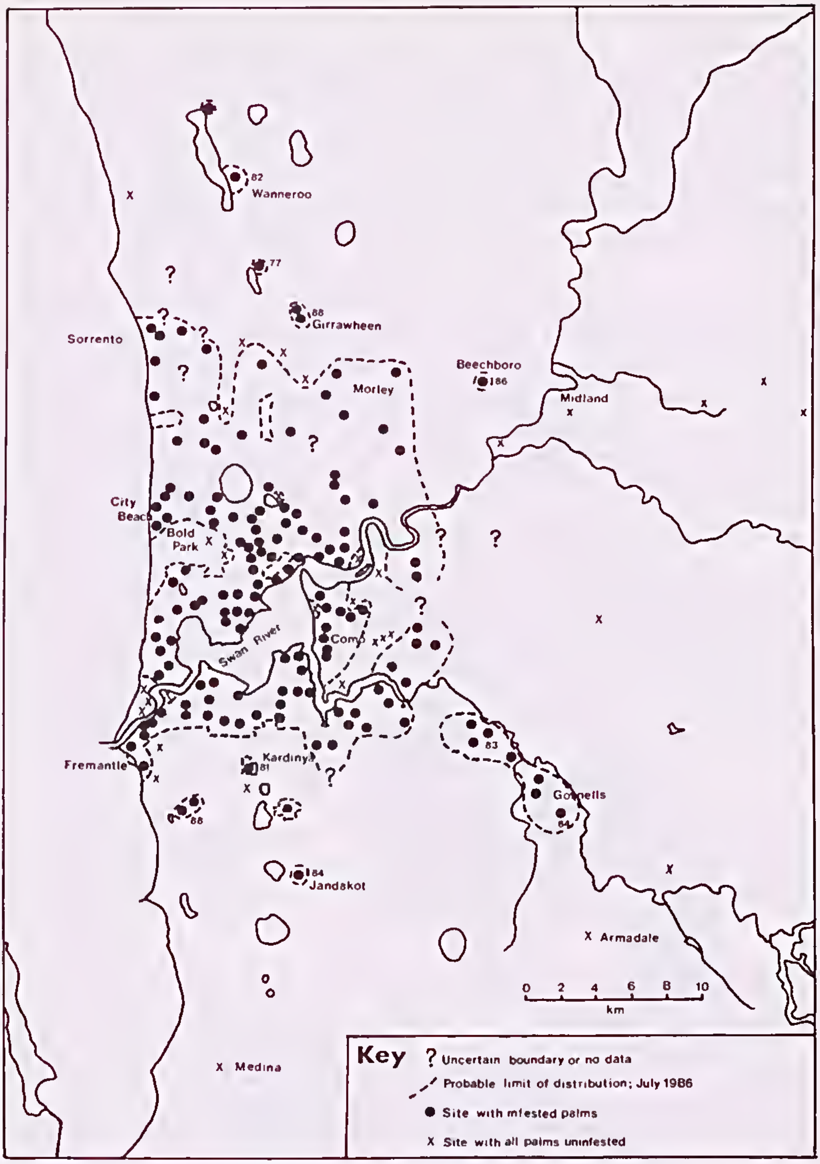


Figure 4. Distribution of the orange palmdart in the Perth region by mid 1986.

C. augiades sperthias has reached some country centres in south-western Australia. It has been recorded from Mandurah and Dawesville since 1984 and also from Margaret River and Esperance. The Mandurah and Dawesville populations are apparently established, but it is not certain if the Margaret River and Esperance populations are. No positive evidence was received that *C. augiades sperthias* occurs in any inland country towns in south-western Australia. *C. augiades sperthias* has also been recorded from further afield in Western Australia. The

Zoology Department of U.W.A. has a specimen of *C. augiades sperthias* labelled Karratha 1984. The W.A. Museum has specimens of the closely related Kimberley, Northern Territory and Cape York species, *C. trichopepla*, labelled Karratha 1984. I also observed this species in Port Hedland in 1982.

Discussion

The colony of palmdarts established in 1977 near Wanneroo remains isolated because the surrounding country lacks palms. However the palmdart has spread to other areas, as shown in Figures 3 and 4. The nodes from which palmdarts have apparently diffused into surrounding areas and the various isolated colonies, support the hypothesis that *C. augiades sperthias* was assisted in its dispersal by humans. The nodal dispersal pattern of the orange palmdart (see Figure 3) may be compared to jumps in the spread of myxomatosis in Britain, which was attributed by Thompson and Warden (1956) to human agency. The isolated colonies (see Figure 4), bears comparison with the map of "The distribution of the rabbit in south-eastern Australia by 1879" (Rolls 1969: 39). Rolls (1969) used this map as evidence that rabbits had not spread to new areas entirely on their own, after their initial introduction. The dates of establishment of some of the isolated orange palmdart colonies also help support the above hypothesis. It seems that orange palmdarts do not fly very far from areas containing palms (tagging experiments could be used to verify this). For example Kardinya has had a population of orange palmdarts since at least 1981. The nearest densely settled areas to Kardinya, did not record any palmdarts until 1986.

The country populations of *C. augiades sperthias* also support the hypothesis that dispersal was human assisted. For example, the palmdart population in Mandurah is likely to have been established by palmdarts brought into the town on palms, during the non adult stage of their life cycle. If palmdarts had managed to fly from Perth to Mandurah, one would expect palmdart colonies to have become established at intervening localities such as Medina and Rockingham. The species had apparently not become established in either locality by mid 1986. In addition, direct evidence of human assisted dispersal exists. Several respondents to my quesionnaire, mentioned purchasing palms on which they had discovered larvae.

The more rapid dispersal northwards, and rates of dispersal southwards as little as 250 metres per year, can probably be attributed to the "extraordinary south-westerly sea breezes with a modal speed of over 16 knots in January and February and over 10 knots between August and April" (Gentilli 1972). The recorded flying period of the orange palmdart in Sydney is from October to April (McCubbin 1971). My observations suggest a similar flying period in Perth, the period of the strongest sea breezes. Thus wind may influence the rate and direction that palmdarts diffuse outwards from the points they have colonized through human agency.

Although the lack of records of *C. augiades sperthias* in inland south-western Australia, east of Gosnells and Thornlie, may be a function of isolation, it may also be due to low winter temperatures. As one moves inland the average winter minimum temperature decreases (Commonwealth Bureau of Meteorology 1966). Several butterfly species, including the chalkhill blue (*Lysandra coridon*) have been documented as having their distributions limited by low temperatures (Cox and Moore 1980). Neither Common and Waterhouse (1981), nor McCubbin (1971) mention any records of *C. augiades sperthias* (which occurs coastally as far south as the Illawarra district) having become established on cultivated palms in inland centres of south-eastern Australia. Simple refrigeration experiments may be able to help answer the question of *C. augiades sperthias'* tolerance to low temperatures.

The rapid spread of the orange palmdart in the Perth metropolitan area in 1984 (Figure 3), can probably be attributed to two factors. First the radially expanding populations from several nodes may have merged. Secondly, by January 1984, *C. augiades sperthias* probably covered a sufficiently large area to make human assisted dispersal highly frequent. By 1984 many nurseries fell within the boundaries of palmdart distribution. If these nurseries had their palms infested by palmdarts, which some report they did, then they would have become effective palmdart dispersal centres. Today most nurseries control the palmdart with insecticides, but eggs laid by adult palmdarts originating from outside the nurseries can easily go undetected. Many new centres of population may have been established in 1984. However these could easily have been obscured as adjacent populations merged.

SPECIES DIVERSITY ON THE HOST PLANT

Results

Figures 5 and 6 show, respectively, the relationship between H' and the number of shelters and between the number of individual arthropods and the total number of species found on palms sampled in April, May and July 1986. The correlation coefficients obtained for each of the above pairs of variables were positive (0.78 and 0.81) and significant (p 0.001). The nature of H' produced a large number of zero values. The correlation between the number of shelters and H' is still strongly positive and significant after removal of the zero values (0.72, p 0.001).

The 150 fronds sampled on the fifty palms used in the survey, were found to contain a total of 47 arthropod species and 223 individual arthropods. Significantly more species (X^2 = 9.9, p 0.01, 1 d.f.) and individual arthropods (X^2 = 67.2, p 0.01, 1 d.f.) were found on infested (44 species and 209 individuals) than on uninfested (6 species and 14 individuals) palms.

The infested palms can be split into two equal groups of 17; palms with one to seven shelters among the 600 leaflets sampled and palms with eight or more shelters per 600 leaflets sampled. The number of species associated with these two groups of palms (20 and 37 respectively), compared with that associated with the uninfested palms (6), helps to emphasise what the correlation between H' and larval shelters has already suggested; more species with increased infestation by the orange palmdart. As one might expect from looking at Figure 6 together with Figure 5, the number of individual arthropods found on palm fronds also increases with increased infestation by *C. augiades sperthias*.

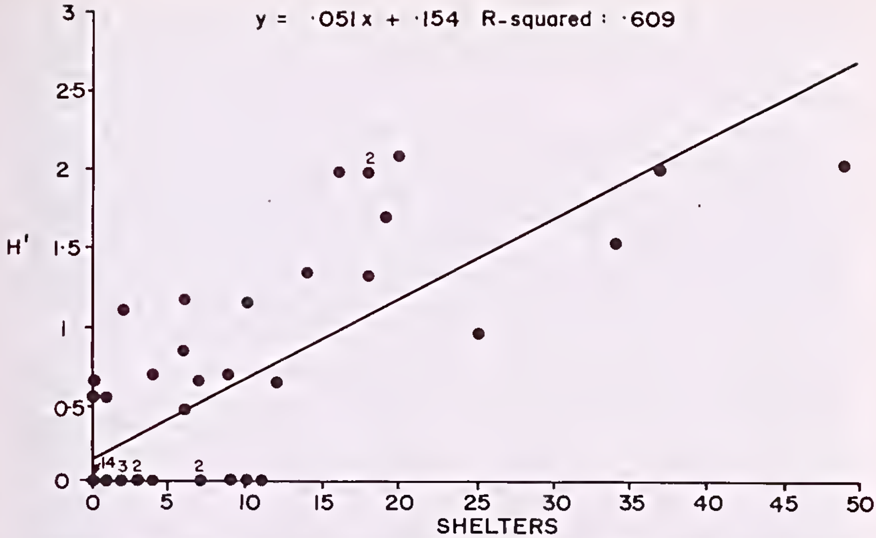


Figure 5. Simple linear regression between the number of shelters found on the fronds of Canary Island date palms and H'. Numerals adjacent to some points on this scattergram indicate values that have been obtained more than once.

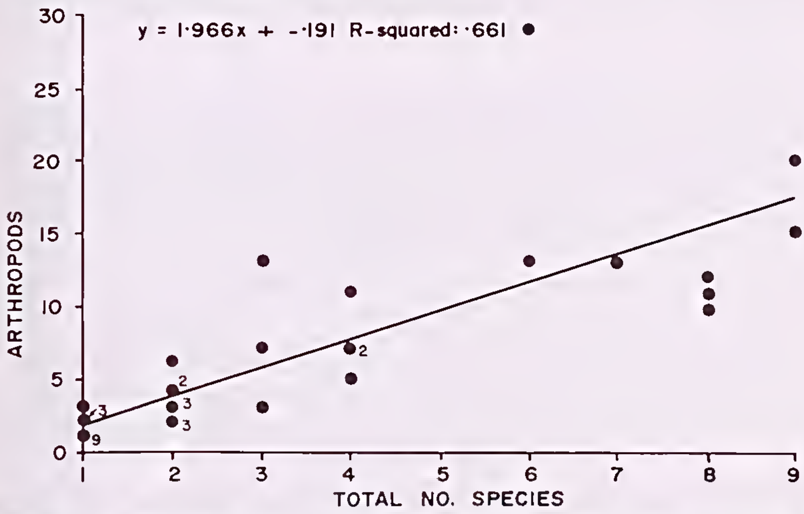


Figure 6. Simple linear regression between the total number of species of arthropods and the number of individual arthropods found on the fronds of Canary Island date palms. Numerals adjacent to some points on this scattergram indicate values that have been obtained more than once.

Fourteen were associated with the 16 uninfested palms, 78 with the 17 slightly infested palms and 131 with the 17 most highly infested palms.

Discussion

Figure 5 indicates increasing species diversity with increasing infestation by the orange palmdart. If the total number of individuals increases with increasing species richness, this implies greater division of niches (Southwood et al. 1982). If there is no relationship between species richness and arthropod abundance, this would suggest competition between species for the same recource. In other words the establishment of any new species using the same recource as other species would increase competition, thus reducing the population of species already present. However the total number of all individuals would remain about the same. If one species can out-compete another, the lesser competitor may be pushed to extinction (Price, 1975), thus species diversity will remain low and arthropod abundance relatively constant when there is little or no niche segregation.

The strong and significant correlation obtained between the total number of species and the number of individual arthropods collected from the sampled palms, implies little competition between species, and thus an increase in the number of niches available. The X^2 test and raw figures presented above also suggest that fronds of *P. canariensis* infested by orange palmdarts, in particular the more highly infested ones have a capacity to support more individual arthropods and more species than uninfested ones. When one considers that H' (which is calculated using both the number of species and number of arthropod data) was strongly and significantly correlated with the number of larval shelters, it seems that increased availability of niches can be attributed to orange palmdart larvae and their shelter constructing habit.

As stated, orange palmdart larval shelters probably form the bases of new ecological niches. Of the arthropods collected on palms with shelters, 44.5 per cent of the individuals and 41 per cent of the species were found in larval shelters. These proportions are higher for palms with eight or more shelters per 600 leaflets, being 50 per cent and 49 per cent respectively.

One major reason why the shelters are used by such a large proportion of arthropods and species is probably due to the protection they provide from predators. During the survey several cockroaches were found undergoing ecdysis (a particularly vulnerable stage) in the shelters. Some spiders with broods were also found occupying larval shelters. These spiders were probably taking advantage of the protection afforded to their offspring by these shelters. Several paper wasps (*Polistes humilis*) were found occupying shelters too. Usually this species builds nests of its own, but apparently it was using palmdart shelters in which to hibernate. Members of the spider family Clubionidae were the most common spiders in the shelters. According to Main (1966: 77) these spiders build silk retreats in rolled-up leaves and amongst foliage. Evidently these spiders found larval shelters a suitable place in which to construct a retreat. These spiders probably use the shelters as a protective cover in the day, emerging at night to hunt. I even observed one group of spiders, the Salticidae, using the palmdart larval shelters as a cover from which to ambush prey. Members of the Salticidae family were encountered infrequently.

Shelters tend to collect palmdart larval faeces, shed larval skins remains of dead larvae and empty pupal cases. My observations suggest these organic remains form the bases for new food chains. Two species of cockroach were found associated with these remains together with collembolans (springtails) and coccinellids (ladybirds).

Coccinellids usually perform the role of a predator (Britton 1970), but of the five species found on the fronds of infested palms, all except *Coccinella repanda* were observed performing the role of a scavenger. It is possible that the Coccinellids were initially attracted to the palms by small hemipterans such as the palm scale *Parlatoria proteus*, which was the only phytophage apart from the *C. augiades sperthias* larvae commonly encountered on surveyed palms. Perhaps upon discovering a new food source in the remains of palmdart larvae, they have adapted to a new role as scavengers and have taken up residence in the protected environment provided by the larval shelters. It is probable they still prey on insects such as *P. proteus* when the opportunity arises. The exact role of Coccinellidae would be well worth investigating.

Scavengers make up 20 per cent of the species collected from slightly infested palms and 24 per cent of the species collected from highly infested palms. They also make up 32 per cent and more than 33 per cent of the individual arthropods found on slightly infested and highly infested palms respectively. No scavengers were collected from uninfested palms, therefore scavengers make up an important new element in the fauna associated with the fronds of *P. canariensis* after invasion by the orange palmdart.

Twenty two predatory arthropod species (including Coccinellids) were found on highly infested palms (palms with eight or more shelters per 600 leaflets), but only three (two Clubionidae species and one Argiopid species, a total of five individual arachnids) were collected from the 16 uninfested palms. Individuals from the spider families Clubionidae, Argiopidae and Theridae were the most frequently encountered predators on infested palms in that order. The wasp *Polistes humilis* was another predatory species often encountered on infested palms. It was frequently observed searching palm fronds. As the larvae of this species are chiefly fed on masticated caterpillars (Reik 1970: 936) it is possible that they were searching for palmdart larvae. *P. humilis* was introduced to Western Australia in 1950 (Koch 1980), thus it is possible that this species was pre-adapted to prey on palmdart larvae.

The low numbers of predators found on uninfested palms indicates the lack of prey available on such palms. Since very few species and individual arthropods were recorded from the fronds of uninfested Canary Island date palms it was assumed that the spiders found on these plants depended on "tourist" species for prey. Tourist species are here defined as species that do not have a permanent association with palm fronds, for example adult Chironomids may frequently settle on the fronds of palms, but equally, they may settle on a fence post or a dead tree stump. Chironomid remains were found in the web of a *Tetragnatha* species (Argiopidae) on an uninfested palm.

Eight Diptera species were collected from infected palms' fronds, but only two species were collected from uninfested palms' fronds (both Chironomidae). If the infested group of palms is divided into its slightly and highly infested groupings, which have five and eight Diptera species respectively, then significant differences between the number of Diptera species associated with each group of palms can be shown ($X^2 = 13.88$, $0.001 < p < 0.01$, 2 d.f.). This suggests that some of the Diptera species on the infested palms are probably more than just tourists. Perhaps some of these species were attracted by palmdart larval remains or faeces. Higher rates of infestation by palmdart larvae would increase scavenging opportunities, therefore more species would be expected to be found. In the absence of any observations that any Diptera were actually feeding on larval remains all Diptera species have been tentatively classified as tourists. Diptera species were found to be the bulk of the diet of the Argiopidae found on the infested palms. The number of individual Argiopidae on palms infested by palmdart larvae was 22 times greater than the number on uninfested palms. The increased abundance of this group on palms attacked by *Cephrenes* larvae, supports the assumption made earlier that some Diptera species are attracted to infested palms. The other spider species were assumed to feed on Diptera species roosting on the fronds, on the scavenging species such as the cockroach *Methana marginalis* and ironically on species attracted by the protection offered by palmdart larval shelters.

Three bird species have also been linked to the network of species associated with the infested fronds of Canary Island date palms. Singing honeyeaters (*Lichenstomus virescens*) have learned to capture palmdart larvae from their shelters. Several palm enthusiasts have claimed that this behaviour is very recent and stated that it appears to have reduced the degree of infestation on their palms. All reports of this behaviour came from areas that had been invaded by the orange palmdart for at least three years. Red wattle birds (*Anthochaera carunculata*) have also been observed eating palmdart larvae. It is reasonable to assume that the two species above, would also eat other species of arthropods they came across on palm fronds, whilst searching for palmdart larvae. Finally the willy wagtail (*Riphidura leucophyx*) has been observed capturing and eating *C. augiades sperthias* adults. Thus this species has become indirectly associated with the fronds of *P. canariensis* through the life cycle of the butterfly.

CONCLUSIONS

The orange palmdart has been able to invade much of the Perth metropolitan area and several coastal country towns. The dispersal pattern consisting of isolated colonies and various nodes from which palmdarts have apparently diffused into surrounding areas and the discovery of larvae on purchased palms support the hypothesis that the orange palmdart was assisted in its dispersal by humans. If such assistance continues it is likely that the palmdart will invade more areas. Due to lower winter minimum temperatures in inland areas it is possible that only coastal centres will be the sites of successful colonization. The effect of temperature on palmdart survival needs experimental verification.

The way in which *C. augiades sperthias* has entered Western Australia (on palms imported from eastern Australia) demonstrates the importance of quarantine measures not only for international items, but for domestic ones also. The mechanism by which the palmdart has extended its distribution within Western Australia leads me to advise people to thoroughly check any plants they purchase, or obtain from friends, for possible pest species. In this way, the opportunities for pest species to rapidly extend their range will be reduced.

Palms in areas that have been invaded by the orange palmdart can be expected to have a more diverse assemblage of fauna associated with their fronds than palms that occur in areas free of orange palmdart infestation. As demonstrated this is due to the use of palmdart larval shelters by additional species because of the cover they provide and due to the formation of new food chains directly involving *C. auglades sperthias* or the additional species attracted to the larval shelters. This is in agreement with the second hypothesis made in the introduction of this article. Although Elton (1958) has documented the re-accumulation of species by exotic plants, he apparently did not predict any dramatic increases in species diversity, resulting from the introduction of a single species as has been documented in this study. Based on this study, it may be possible to increase the diversity of fauna associated with exotic plants that have invaded indigenous vegetation by introducing host specific phytophages that modify plant structure (such as borers and certain butterfly and moth larvae) to create potential refuges and organic traps.

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MAMMALS OF THE DARLING SCARP, NEAR PERTH

By J. DELL and R.A. HOW, Western Australian Museum, Francis Street, Perth, 6000

INTRODUCTION

In a review of the information available on the Darling Scarp, Dell (1983) concluded that there was a need for comprehensive biological surveys as a precursor to conservation and management strategies. In 1984 the Western Australian Naturalists' Club began an intensive survey of a section of the Scarp consisting of natural bushland south of Welshpool Road at Lesmurdie. This survey examined various vertebrate communities and the flora of the area; a series of papers will present data on each of these groups. The Naturalists' Club and the W.A. Museum collaborated to census mammals, the results of which are included in this report.

METHODS AND STUDY SITES

An area south of Welshpool Road at Lesmurdie (Figure 1) was selected because it is relatively undisturbed and is continuous with the Jarrah, *Eucalyptus marginata*, woodland of the lateritic plateau.

Three types of metal traps were set in seven localities selected to represent the vegetational heterogeneity across the range of elevations from the base to the top of the scarp. Each trapline consisted of one cage trap (23x23x66cm), seven Elliotts (9x9x32cm) and two large Elliotts (16x15x45cm). The traps were spaced approximately 10 metres apart and usually under vegetation shelter. Traps were baited with peanut paste, oats and bacon (cages and large Elliotts also with apples) and run for five successive days (six days in May) during June, September and October 1984 and February, April, May and July 1985. During these sessions traps were checked for captures at dawn each morning. Sightings of species and observations on scats, tracks and diggings were recorded. Bats were not sampled and, because of the rocky nature of the area, pit-traps were not used. Accordingly some small marsupials were not adequately sampled. Data in text are presented as mean, ± one standard deviation and (sample size).